PATHFINDER

BIOREGENERATIVE LIFE SUPPORT REQUIREMENTS PROGRAM PLAN

April 1989

Office of Aeronautics and
Space Technology

Washington, D.C. 20546

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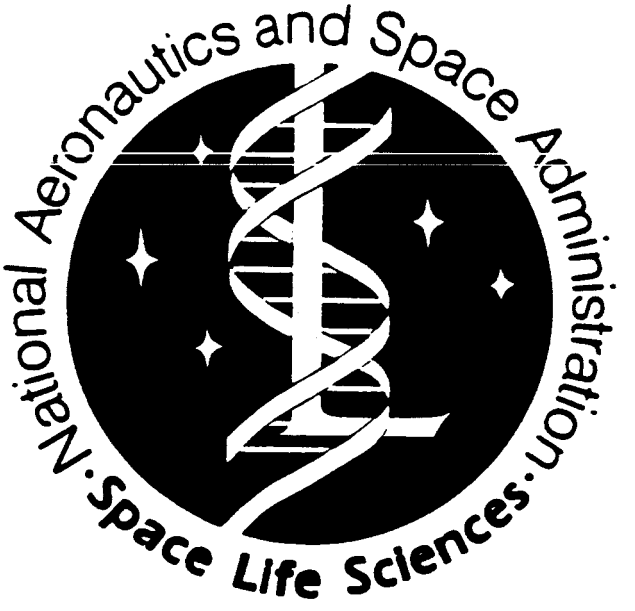

Office of Space Science
and Applications

National Aeronautics and Space Administration
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BIOREGENERATIVE LIFE SUPPORT PROGRAM PLAN

April 1989

Approved By:

Program Manager, Life Sciences Division — Date 4/17/89

Approved By:

Director, Life Sciences Division — Date 4/17/89

Approved By:

Pathfinder Program Manager, Space Directorate — Date 6/20/89

Office of Space Science and Applications

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FOREWORD

Pathfinder is a research and technology initiative by the National Aeronautics and Space Administration (NASA) which will strengthen the technology base of the United States civil space program and provide options for potential future space exploration missions. These missions may include an intensive study of the Earth, a return to the Moon, piloted missions to Mars, or the continuing robotic exploration of the Solar System. Pathfinder is managed by the NASA Office of Aeronautics and Space Technology, to advance critical technologies for these missions and ensure technology readiness for future national decisions regarding exploration of the Solar System. Pathfinder extends the technological foundation being established by the Civil Space Technology Initiative, which focuses on advancing a family of technologies for transportation to and operations in near-Earth orbit and supporting science activities. Pathfinder looks toward longer-term missions beyond Earth orbit and into the Solar System.

Four major thrusts of Pathfinder are Surface Exploration technology, In-Space Operations technology, Humans-in-Space technology, and Space Transfer technology. The Humans-in-Space thrust will provide the critical technologies to enable or enhance future long-duration piloted exploration missions. A key element of this thrust is the Bioregenerative Life Support Program, managed by the Biological Systems Research Branch, Life Sciences Division, in NASA's Office of Space Sciences and Applications. The Pathfinder Bioregenerative Life Support sub-program will determine the engineering and system performance requirements for biologically-based systems and subsystems technologies to provide food production, processing, and waste management. Emphasis will be on providing an early food supplementation capability for exploration missions.

This Program Plan describes the goals and objectives, management plan, technical approach, resources and financial management plan, facilities plan and technology transfer planning for the Bioregenerative Life Support sub-program of Pathfinder. For additional information on the Bioregenerative Life Support Program, please contact:

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SECTION 1

EXECUTIVE SUMMARY

1.1 Program Goals and Objectives

CONTEXT OF THE PATHFINDER ACTIVITIES

This sub-program represents an enhancement to the NASA Controlled Ecological Life Support System (CELSS) program. The CELSS program is managed in the Life Sciences Division within the Office of Space Science and Applications (OSSA). The Pathfinder program will provide funding for specific technology activities relevant to the use of CELSS on future exploration missions. Under Pathfinder, the Bioregenerative Life Support sub-program will determine the engineering and system performance requirements for biologically-based systems and subsystems technologies to provide food production, processing, and waste management. This will be done in the context of the overall program being pursued independently by OSSA.

CELSS PROGRAM GOAL

Develop a bioregenerative life support system by combining biological and physico-chemical processes capable of recycling the food, air and water needed to support long-term human missions in space.

PATHFINDER BIOREGENERATIVE LIFE SUPPORT OBJECTIVES

1. Define the technological requirements for providing a source of fresh food as a dietary supplement for long-duration missions.

2. Develop technology requirements for candidate food processing and waste management facilities that best accommodate functional, operational, and environmental requirements of advanced lunar and Mars missions.

3. Utilizing the Office of Exploration (OEXP) advanced mission scenarios, identify the specific life support requirements imposed by each scenario and determine how a complete bioregenerative life support system (CELSS) might satisfy those life support requirements.

1.2 Organization and Management

The Bioregenerative Life Support Program will be planned and implemented in three broadly-defined elements. Element I will focus on the definition of requirements for crew diet supplementation using fresh salad vegetables. Element II involves studies in the areas of food production and processing subsystem technologies, and waste management subsystem technologies, for lunar and Mars missions. Element III will involve a

continuing analysis of advanced missions scenarios that are needed to enhance the effectiveness of CELSS subsystems and systems for application to advanced missions.

The Bioregenerative Life Support Program in Pathfinder is organized into a work breakdown structure which reflects these elements (Figure 1.1).

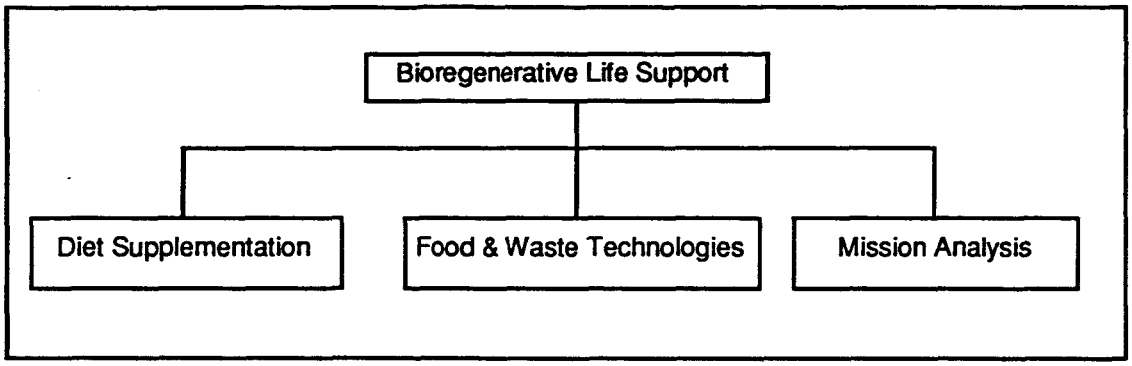

Figure 1.1 Pathfinder Bioregenerative Life Support Program Work Breakdown Structure

The Bioregenerative Life Support Program will be managed from the Life Sciences Division in the Office of Space Sciences and Applications, within the Biological Systems Research Branch (Code EBR), NASA HQ. The Program Manager assumes overall responsibility for the direction and execution of the program, for new program plans and for management and coordination of program elements. Ames Research Center, Johnson Space Center, Kennedy Space Flight Center and other Centers will play key roles in the technical design, implementation and reporting of this program. No lead center has been named, but participating centers have been given distinct roles and responsibilities. Advice is provided by the Aerospace Medicine Advisory Committee within NASA, and by the Aeronautics and Space Engineering Board of the National Research Council outside of NASA. Coordination of the Bioregenerative Life Support Program and other elements of Humans-in-Space will be through the Pathfinder Program Manager. Figure 1.2 indicates the Phase I Bioregenerative Life Support Program management structure.

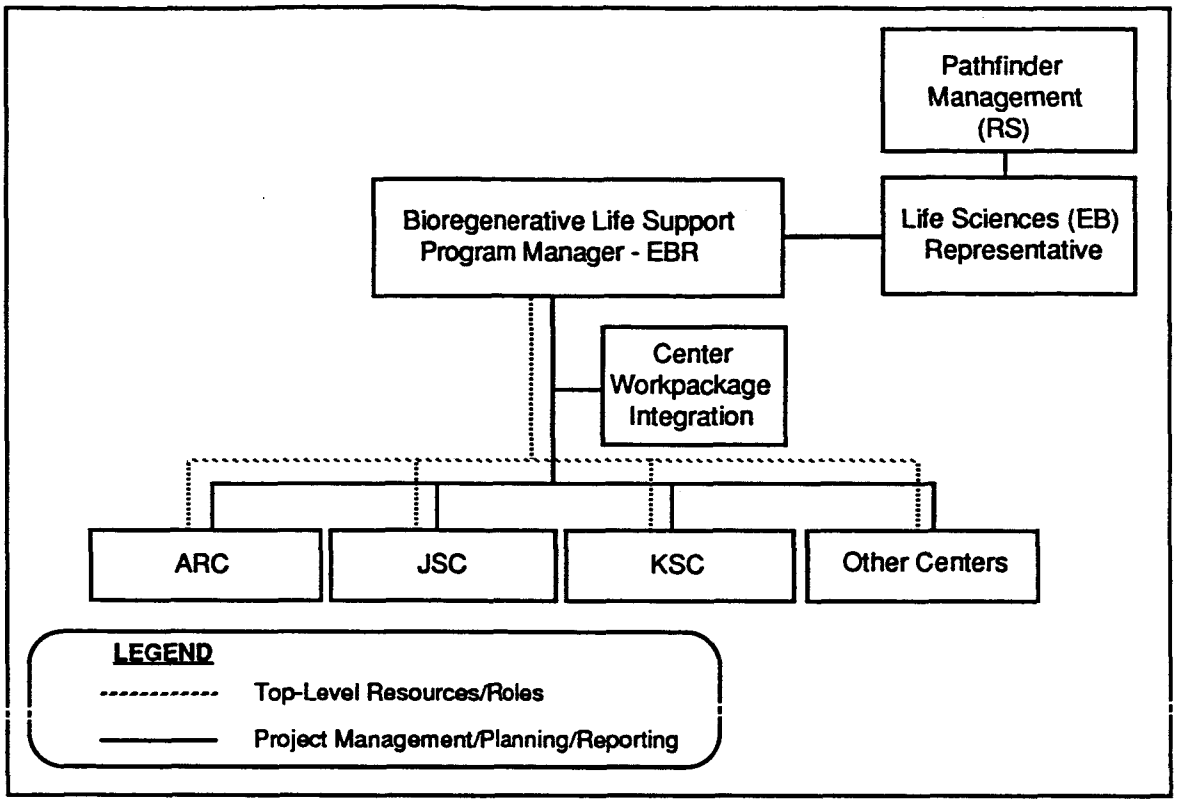

Figure 1.2 Pathfinder Bioregenerative Life Support Program Management Structure

1.3 Schedule and Deliverables

This program will be organized to meet its Phase I planned objectives in the first five year period of the Pathfinder Program.

By the completion of the initial phase of the Pathfinder Program, requirements will be in place to guide the development of the relevant food production, processing, and waste management technologies (conditional upon the availability of required resources). In the area of food production, descriptions of the environmental requirements for optimal crop production will be provided. Included will be studies on the production of salad vegetables for diet enhancement as well as major food crops for meeting total nutritional requirements. Studies on the technological requirements for processing the raw food materials into edible foods will be completed. Definition of waste management technologies required to convert solid, liquid and gaseous wastes into usable system inputs will be completed. Mission accommodation studies will be based upon the scenarios for advanced missions as developed by the Office of Exploration.

The programmatic deliverables will be:

1. Technology requirements for salad vegetable growth for diet enhancement.

2. Technology requirements for CELSS subsystems for crop plant growth, waste and food processing for lunar and Mars Bases.

3. Mission-specific bioregenerative life support system technology and configuration requirements.

1.4 Resources

Projected pathfinder resource requirements for this activity for fiscal years 1989 through 1993 are approximately $4.25 million (Table 1.1). Resources allocated for FY 1989 total $250 thousand. This initial level of funding will allow only minimal progress in attaining the objectives of this program as outlined in this plan

Table 1.1 Resource Requirements for Bioregenerative Life Support

RESOURCES	SCHEDULE (FISCAL YEAR)				
	1989	1990	1991	1992	1993
Funding ($, M)	.25	.50	1.00	1.00	1.50
NASA Workforce (WY/Year)	TBD	TBD	TBD	TBD	TBD

SECTION 2

INTRODUCTION

2.1 Pathfinder Program Overview

Pathfinder is a National Aeronautics and Space Administration (NASA) initiative to develop critical capabilities to support the future of the U.S. civil space program. Pathfinder does not, in itself, represent a commitment to any particular mission. However through Pathfinder, NASA will develop a variety of high-leverage technologies that can be applied to a wide range of potential future NASA solar system exploration missions. Pathfinder is organized into four research and technology program areas: (1) Surface Exploration, (2) In-Space Operations, (3) Humans-In-Space, and (4) Space Transfer. The Bioregenerative Life Support Program is one of the five sub-programs in the Pathfinder Humans in Space technology thrust. Additional information on Pathfinder can be found in the Pathfinder Program Plan.

2.2 Document Purpose and Scope

This document is the Bioregenerative Life Support Program Plan. The purpose of this program plan is to provide the scope, content, and long-range plans of the Bioregenerative Life Support Program within Pathfinder. The objectives of this document are: (1) to provided traceability to mission-derived technology requirements; (2) to specify the top-level work breakdown structure; (3) to define technical goals and objectives for the program and its major work packages; (4) to define the management responsibilities and accountability; (5) to establish resource allocations, and associated schedules, milestones, and deliverables; and (6) to document long-range Pathfinder Bioregenerative Life Support program planning.

SECTION 3

Bioregenerative Life Support PROGRAM OVERVIEW

3.1 Mission Studies and Technology Requirements

The NASA Controlled Ecological Life Support System (CELSS) program was initiated with the premise that NASA's goals would eventually include extended-duration missions with sizeable crews requiring capabilities beyond the ability of conventional life support technology. Currently, as mission duration and crew size increase, the mass and volume required for consumable life support supplies also increases linearly. Under these circumstances the logistics arrangements and associated costs for life support resupply will adversely affect the ability of NASA to conduct long-duration missions. A solution to the problem is to develop technology for the recycling of life support supplies from wastes. This technology has been emphasized recently in studies by OEXP, as well as in reports by the Space Sciences Board and the Aeronautics and Space Engineering Board of the National Research Council.

The CELSS concept is based upon the integration of biological and physico-chemical processes to construct a system which will produce food, potable water and a breathable atmosphere from metabolic and other wastes, in a stable and reliable manner. A central feature of a CELSS is the use of green plant photosynthesis to produce food, with the resulting production of oxygen and potable water, and the removal of carbon dioxide.

3.2 Technology Assessment

Currently envisioned physical-chemical life support systems, such as the system being developed for Space Station Freedom, are intended to recycle the air and water needed by the crew to the maximum possible degree. Systems able to completely recycle air and water are not yet under development, and at best such a system will require the provision of stored food and the removal of waste materials. In comparison even to a system capable of recycling 100% of air and water, the development of an operational CELSS will provide economic, psychological and mission operations benefits. For long-duration missions, such as permanent Lunar or Mars bases where logistics supply is very costly or impractical, the development of a fully integrated bioregenerative life support system will be enabling. As the duration of future manned space missions increases, a crossover point is reached where it will be more economical to provide life support supplies by the recycling of metabolic and hygiene wastes than to incur the repeating costs of the resupply of food. In-situ regeneration of life support consumables will protect the mission from the adverse effects of unpredictable interruptions in the logistics train.

The availability of fresh foods such as grains, salad greens and other vegetables, and the sense of autonomy inherent in a fully recycling life support system will also have a positive effect upon crew psychology and productivity, thereby contributing to the ultimate success of the mission. Early efforts to provide these foods are thought to have a large potential leveraging effect for the establishment of extraterrestrial outposts.

3.3 Program Goals and Objectives

CELSS PROGRAM GOAL

Develop a bioregenerative life support system by combining biological and physico-chemical processes capable of recycling the food, air and water needed to support long-term human missions in space.

PATHFINDER BIOREGENERATIVE LIFE SUPPORT OBJECTIVES

1. Define the technological and engineering requirements for providing a source of fresh food as a dietary supplement for long-duration missions.

2. Develop engineering and technology requirements for candidate food production, processing, and waste management facilities to best accommodate functional, operational, and environmental requirements of advanced Lunar and Mars missions.

3. Utilizing Code Z advanced mission scenarios, identify the specific life support requirements imposed by each scenario and determine how a complete bioregenerative life support system (i.e., CELSS) might satisfy these life support requirements.

3.4 Technical Approach

The general approach to CELSS development activities is to first identify requirements for system and subsystem operations, and then to accomplish successive stages of prototype component and system development, based upon and supported by appropriate ground-based and flight experiments. Based on this strategy, the development of operational space systems can begin soon after the turn of the century. A CELSS can be viewed as an integrated set of biological and physico-chemical subsystems, functioning through processes of regeneration and recycling, to sustain human life. Major subsystems for a CELSS include:

1. Biomass production (plant and secondary animal production)
2. Biomass processing (food production from biomass)
3. Water purification
4. Air revitalization
5. Solid waste processing
6. System monitoring and control

These subsystems are interactive and interdependent, often sharing plants as a common processor. Research needs include both ground-based and flight studies that range from determining the environmental requirements for optimal plant productivity and the effects of micro-gravity on plant growth, to the problems inherent in the development of the

technology required for the recycling of human and plant wastes. The development of these subsystems, their integration, and the characterization of mission-specific CELSS variants are described elsewhere, in the CELSS Program plan.

The Pathfinder Program will provide information with regard to a portion of the total CELSS program described above. Specifically, Pathfinder tasks will provide requirements for the development of technology for providing a source of fresh food as a dietary supplement for long-duration missions, including candidate food processing and waste management facilities for advanced Lunar and Mars missions. Utilizing Code Z advanced mission scenarios, the program will identify the specific life support requirements imposed by each scenario and determine how a complete Bioregenerative Life Support System (CELSS) might satisfy these life support requirements.

SECTION 4

ORGANIZATION AND MANAGEMENT

4.1 Overview

The Bioregenerative Life Support Program will be planned and implemented in two broadly-defined phases. Phase I will initiate studies in areas of food production and food processing subsystem technologies, and waste management subsystem technologies. Phase I will also focus on the definition of mission-specific bioregenerative life support requirements. Phase II will involve a continuing study of the definition of advanced technologies that are needed to enhance the effectiveness of CELSS subsystems and systems for application to advanced missions.

4.2 Work Breakdown Structure

The Bioregenerative Life Support Program will be planned and implemented in three broadly-defined elements. Element I will focus on the definition of requirements for crew diet supplementation on early missions of exploration, using fresh salad vegetables. Element II involves studies in the areas of food production and processing subsystem technologies, and waste management subsystem technologies, for lunar and Mars missions. Element III will involve a continuing analysis of advanced missions scenarios to that are needed to enhance the effectiveness of CELSS subsystems and systems for application to advanced missions. The Bioregenerative Life Support Program work breakdown structure reflects this programmatic organization and consists of three work packages (Figure 4.1)

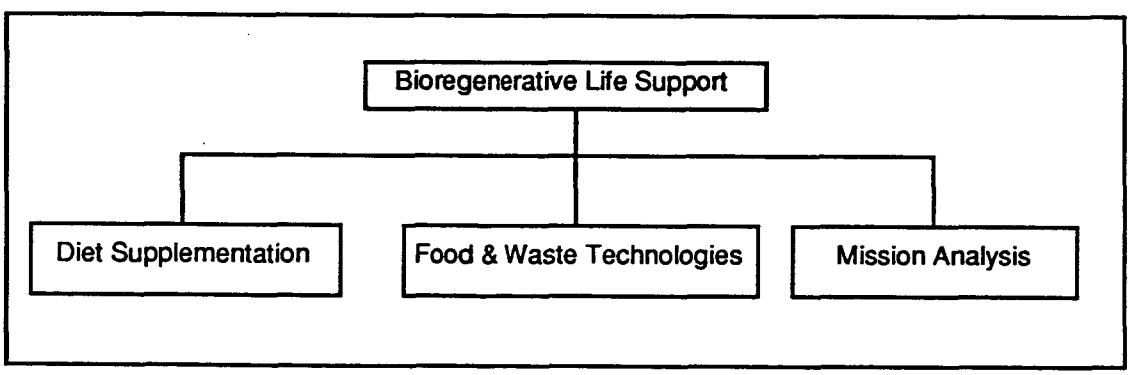

Figure 4.1 Pathfinder Bioregenerative Life Support Program Work Breakdown Structure

4.3 Management Structure

The Bioregenerative Life Support Program will be managed by the Biological Systems Research Branch (Code EBR) in the Life Sciences Division, Office of Space Sciences and Applications, NASA HQ. The CELSS Program Manager assumes overall responsibility for the direction and execution of the program, for new program plans and for management and coordination of program elements. Ames Research Center, Johnson Space Center, Kennedy Space Flight Center and other Centers will play key roles in the technical design, implementation and reporting of this program. No lead center has been named, but participating centers have been given distinct roles and responsibilities in the Program, as in the CELSS program currently underway. Advice is provided by the Aerospace Medicine Advisory Committee within the NASA Advisory Council, and by the Aeronautics and Space Engineering Board of the National Research Council, outside of NASA. Coordination of the Bioregenerative Life Support Program and other elements of Humans-in-Space will be through the Pathfinder Program Manager. Fig. 4.2 indicates the Phase I Bioregenerative Life Support Program management structure.

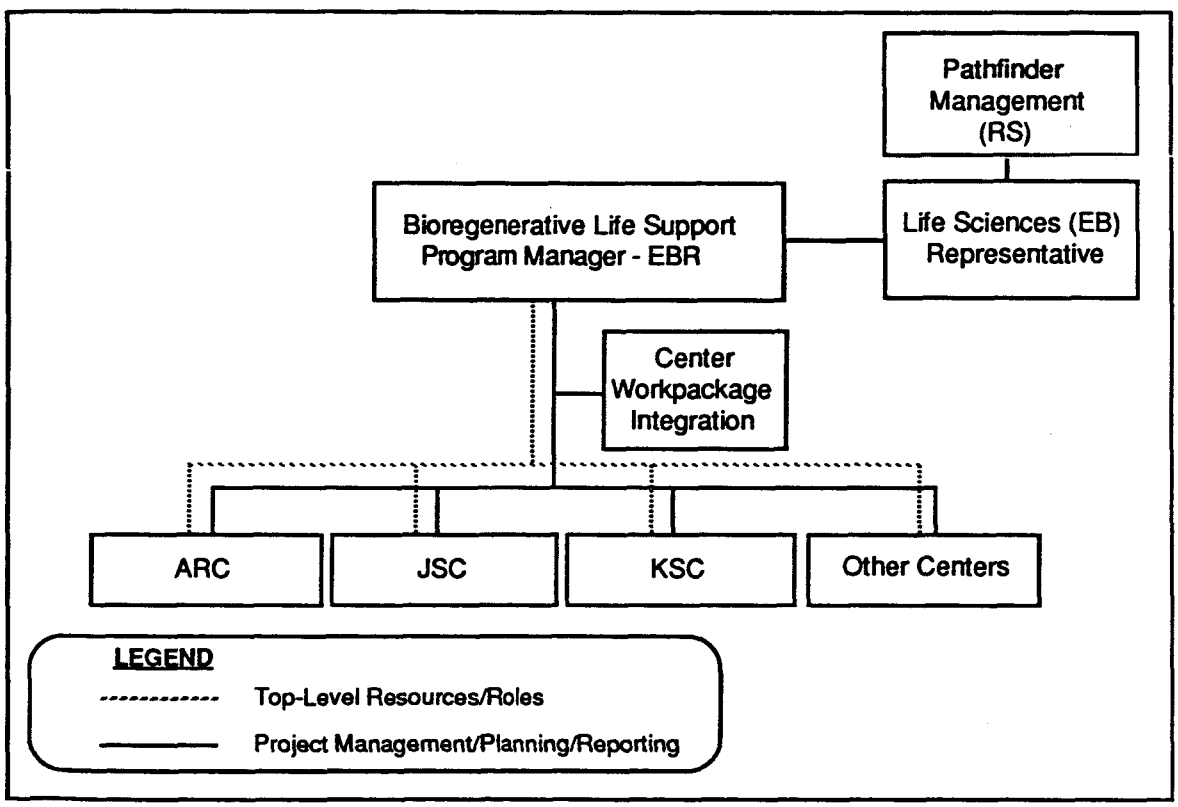

Figure 4.2 Bioregenerative Life Support Program Management Structure

4.4 Program Coordination

The CELSS program is integrated with programs in Space Medicine, Environmental Monitoring, Gravitational Biology, Biological Systems Research, and their related flight components within the Life Sciences Division (EB) in OSSA. Coordination between the CELSS Program and the Physical-Chemical Closed-Loop Life Support program within the Office of Aeronautics and Space Technology will be accomplished through direct contact at the Headquarters level, and through research and development activities at participating Field Centers. Liaison is also maintained with the Office of Exploration, through the Life Sciences Division Pathfinder point-of-contact, who is also designated as the Division representative to OEXP.

The CELSS Program Manager in EB has also established a CELSS Coordinating Committee to provide a forum for intercenter contact among the CELSS program elements located at Ames Research Center, Johnson Space Center, and the Kennedy Space Center. This Coordinating Committee also includes the participation of Astronauts from the Johnson Space Center.

Preparation for advanced space missions as represented by the Bioregenerative Life Support Program evolves from, and builds on, related life science activities. In all cases the existing Supporting Research and Technology (S R & T) Program (the CELSS Program) will continue to provide baseline information from which advanced needs can be anticipated and studied.

4.5 Program Planning and Documentation

A detailed Bioregenerative Life Support Project Plan will guide the first five-year, technology development phase of the effort. This plan will be developed and maintained cooperatively among the participating NASA Field Centers and the Life Sciences Division, OSSA. The Center with primary activity in an area will be responsible for coordinating and documenting that area activity, and the Life Sciences Division, HQ will integrate areas and produce the final Project Plan document. The authority to resolve conflicts will reside with the EB Bioregenerative Life Support Program Manager.

The Project Plan will determine project content, Center responsibilities, resource allocation, and milestones. Project activities will be formally reviewed each year. During this review, there will be an opportunity for each Center to participate within their particular areas of expertise, and the Project Plan will be modified as required. A Project Plan for additional phases of Pathfinder will be developed at the completion of Phase I.

4.6 Program Reporting

4.6.1 Quarterly Status Report

Program reporting documentation will consist of quarterly technology project reports, submitted by the Bioregenerative Life Support Program Manager to the Pathfinder Program Manager. These reports will track progress against milestones and schedules. These reports will also identify and track any problems and/or issues, as well as potential corrective actions.

4.6.2 Annual Report

An annual report will be prepared by the Bioregenerative Life Support Program Manager, summarizing the year's accomplishments and progress toward approved technology performance objectives. The annual report will also identify key activities for the next fiscal year.

4.7 Advisory Committees and Working Groups

Technical advice will be provided to the Bioregenerative Life Support Program Manager by NASA's Aerospace Medical Advisory Committee and by the CELSS Discipline Working Group. Additional advice may also be sought from outside groups, such as the Aeronautics and Space Engineering Board.

SECTION 5

TECHNICAL PLAN

5.1 Overview

The Bioregenerative Life Support Program will provide research and analysis on the development of technology requirements for bioregenerative life support systems for the support of crews in advanced missions. The goal of this activity will be to determine the engineering and system performance requirements for biologically-based systems and subsystems to provide food production and processing, and waste management needed to support long duration missions of exploration.

The Bioregenerative Life Support Program technical plan is organized along three major elements which correspond to the major elements of the work breakdown structure: definition studies of CELSS flight hardware to lead to early fresh food supplementation, mission scenario analysis on the application of CELSS for exploration missions, and design studies of CELSS food production and waste management facilities for the exploration missions.

5.2 Fresh Food Supplementation

5.2.1 Description/Status

Present plans for feeding crews on long-duration missions call for a diet consisting of freeze-dried, thermo-stabilized, and frozen foods. No fresh food sources are anticipated. The nutritional and psychological consequences of this type of diet may adversely affect the health, psychological state, and productivity of the crews. The provision of fresh foods as a supplement to presently planned diets will work to prevent these detrimental physiological and psychological effects and will enhance the productivity of the crews.

The objective of this program element is to define the technological requirements for providing a source of fresh food as a dietary supplement for long-duration missions.

The primary function of the fresh food supplementation system will be to grow salad vegetables reliably, allowing crewmembers to harvest them for their consumption. In addition to providing a fresh vegetable food source, the activity of growing plant species by crewmembers will have an intrinsically beneficial effect on the morale and psychological well-being of crewmembers. Of a secondary nature, this system will be designed with the potential for producing potable water from "grey" water, and will provide a small portion of the crew habitat revitalized air supply.

Presently available technology can grow salad vegetables in a reliable and dependable manner. This technology has not, however, been validated in microgravity or reduced gravity. In addition, mission constraints on volume, weight, and power must be met in the development of the plant growth facility.

5.2.2 Work Package Tasks

The major tasks that will be performed as part of this element are:

1. Plant species selection
2. Definition of power requirements
3. Design sizing
4. Subsystem design and development requirements
   a. Nutrient delivery
   b. Thermal control
   c. Air flow
   d. Gas composition control
   e. Lighting
   f. Contamination monitoring and control
   g. System control and data acquisition

5.3 Technology Requirements for Food Processing and Waste Management

5.3.1 Description/Status

Central to CELSS function are the processes that grow food crops, produce edible food, and manage the waste derived from these processes, as well as human wastes.

The purpose of this element is to develop requirements for candidate food processing and waste management facilities. These facilities will be designed to best accommodate functional, operational, and environmental requirements of advanced Lunar and Mars missions.

While various technologies exist that can, in general, provide the necessary functions to carry out these processes, none of them have been tested in the context of a CELSS. It is necessary to carry out a critical review of the existing relevant technologies for carrying out plant growth, food production and waste management in the context of anticipated lunar and Mars bases. This review will identify candidate technologies and include all relevant performance parameters e.g., mass, volume and power. On the basis of this review, alternate design requirements will be developed and subjected to a tradeoff analysis. This review and trade-off study will identify the requirements for the development of specific technologies for food and waste processing for advanced missions.

5.3.2 Work Package Tasks

The major tasks to be performed for this element are:

1. Identify current food production, food processing and waste management technologies and describe their relevant performance parameters.

2. Carry out tradeoff analyses on these technologies.

3. Develop alternate subsystem and system conceptual designs based upon these analyses.

4. Identify technology needs and requirements.

5.4 Mission Scenario Analysis

5.4.1 Description/Status

The development of bases on the moon and Mars are key goals of the advanced planning being carried out by the Office of Exploration. These extraterrestrial settlements are projected to ultimately allow the permanent presence of humans. Such bases would support a variety of activities from commercial to industrial to scientific. A CELSS would be central to the success of these missions, as it would allow for the maximum level of autonomy while significantly reducing the cost of resupply.

Utilizing Code Z advanced mission scenarios, this element will identify the specific life support requirements imposed by each scenario, and determine how a CELSS might satisfy these life support requirements. As part of this analysis, specific CELSS configurations will be identified which will satisfy the mission life support requirements. Each CELSS configuration will be analyzed from the perspective of system properties such as functionality, operations flexibility, the use of *in situ* resources, the developmental sequence, etc.

5.4.2 Work Package Tasks

The tasks to be performed in this element include:

1. Analysis of advanced mission scenarios as to their requirements for life support.

2. Matching scenario-dependent life support requirements to the potential functional attributes and properties of a generic or reference CELSS configuration.

3. Developing alternate configurations to optimally meet life support requirements, and conducting trade studies among these configurations.

4. Identifying technology requirements for those CELSS configurations most beneficial to each mission scenario.

5.5 Five-Year Planning Summary

5.5.1 Schedule

Assuming the resource allocations outlined below, by the completion of the initial five year period of Pathfinder (Phase I), preliminary requirements will be in place to guide the development of technologies for food production, food processing and waste management for Lunar and Mars manned missions. In the area of food production, descriptions of candidate technologies for the growth of crop plants for both dietary enhancement and to provide nutritional needs will be in place. In the area of the processing of edible foods from harvested crop plants, technology requirements for candidate technologies will be developed. In waste management, requirements for technologies for processing solid, liquid and gaseous wastes so as to provide for the regeneration of food, potable water and a breathable atmosphere will be identified.

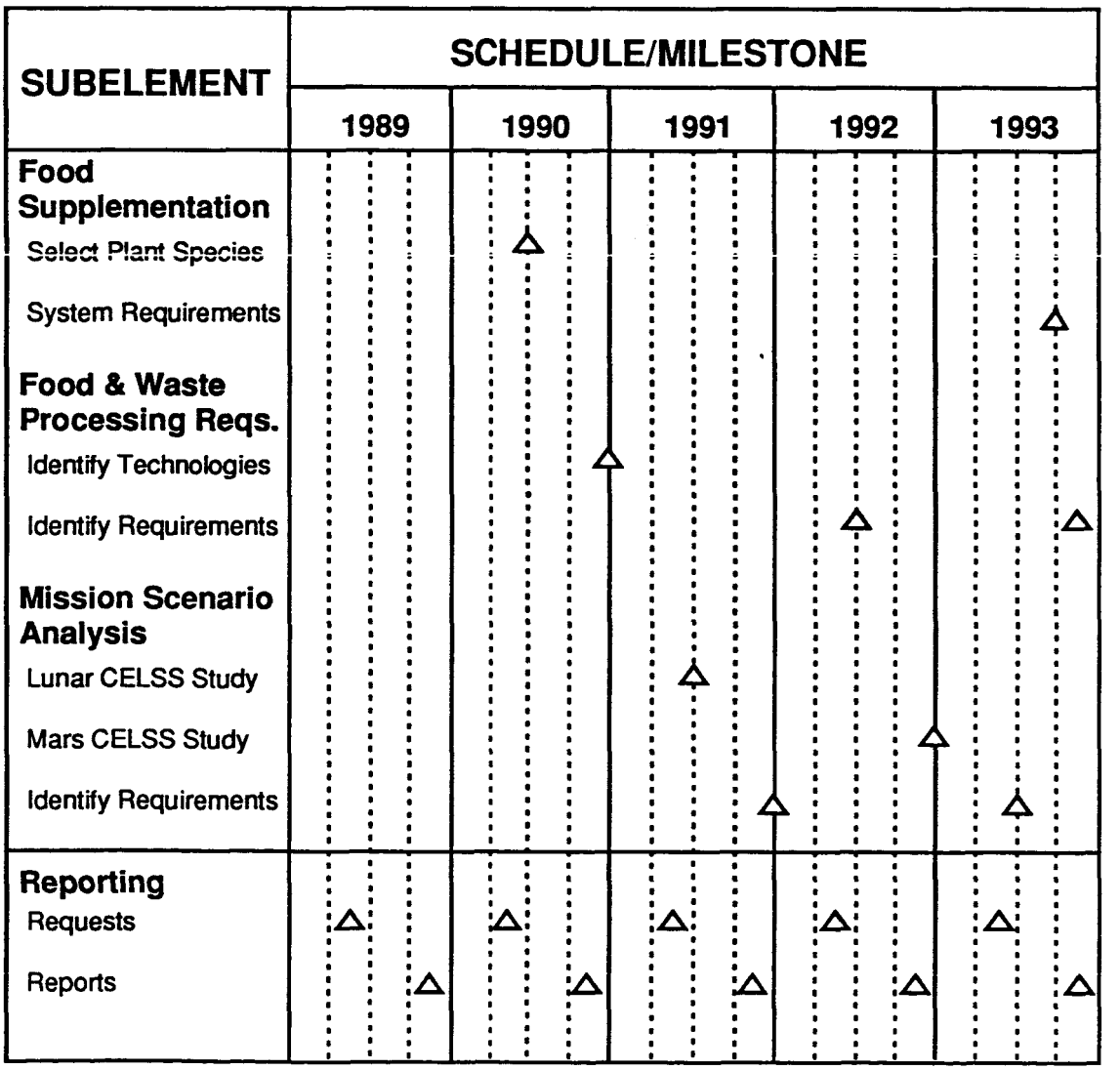

Figure 5.1 Bioregenerative Life Support 5-year Milestones

5.5.2 Milestones

Major milestones for the planned initial five-year of the Pathfinder Bioregenerative Life Support Program are provided in Figure 5.1. Specific work package milestones will be outlined as part of the Project Plan.

5.6 Long-Range Program Plan and Options

During the next phase of the Pathfinder program, the definition of all appropriate Bioregenerative Life Support technology requirements will be completed. The phasing-in of requirements as they become available will allow for technology development to proceed. The development of specific technologies will be influenced by decisions made by the Office of Exploration and commitments made at a national level, as well as by the results obtained in the initial research phase. In addition, specific configurations of entire integrated bioregenerative life support systems appropriate to different mission scenarios will be developed and analyzed.

SECTION 6

RESOURCES AND FINANCIAL MANAGEMENT PLAN

The budget for the Bioregenerative Life Support Program will be provided on a yearly basis by the Pathfinder Program Manager, Office of Aeronautics and Space Technology. The Bioregenerative Life Support Program Manager is responsible for distribution of the budget among work elements. Funding will be distributed and tracked according to the work breakdown structure that will be developed for the Project Plan.

Resource requirements, including both funding and NASA workforce, for FY 1989 and for the remaining four years of Phase I are provided in Table 6.1. A preliminary estimate of funding levels required to support the Bioregenerative Life Support Program during Phase II is given in Table 6.2.

Details of FY 1989 and subsequent years of Phase I will be as shown in the Bioregenerative Life Support Project Plan, including funding and workforce allocations for the individual work packages.

Table 6.1 Resource Requirements - Phase I

RESOURCES	SCHEDULE (FISCAL YEAR)				
	1989	1990	1991	1992	1993
Funding ($, M)	.25	.50	1.00	1.00	1.50
NASA Workforce (WY/Year)	TBD	TBD	TBD	TBD	TBD

Table 6.2 Resource Requirements - Phase II

RESOURCES	SCHEDULE (FISCAL YEAR)				
	1994	1995	1996	1997	1998
Funding ($, M)	2.00	2.50	3.00	3.00	3.50
NASA Workforce (WY/Year)	TBD	TBD	TBD	TBD	TBD

SECTION 7

CONTRACTING STRATEGY AND PLANS

Details of contracting plans and the distribution between in-house, university, and industry activities will be provided in the Bioregenerative Life Support Project Plan.

SECTION 8

FACILITIES STRATEGY AND PLANS

Details of facilities requirements will be provided in the Bioregenerative Life Support Project Plan.

There are currently no facilities dedicated to this effort. Activities underway in the OSSA CELSS program at the Ames Research Center, Johnson Space Center, and the Kennedy Space Center form the basis upon which future work in this field will depend.